(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 865 731 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
23.09.1998 Bulletin 1998/39

(51) Int Cl.6: A01M 13/00, A23L 3/3418, A01M 17/00

(21) Application number: 98302028.0

(22) Date of filing: 18.03.1998

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 18.03.1997 US 819996

(71) Applicant: THE BOC GROUP, INC.
Murray Hill, New Providence,
New Jersey 07974-2082 (US)

(72) Inventors:
- Smithyman, Dennis
Long Valley, New Jersey 07853 (US)
- Schmidt, Carl
Downers Grove, Illinois 60516 (US)
- Six, Sloane
Radnor, Pennsylvania 19087 (US)

(74) Representative: MacLean, Martin David
The BOC Group plc,
Chertsey Road
Windlesham, Surrey GU20 6HJ (GB)

(54) Gas fumigation

(57) A method and system for fumigating a region with a non-flammable gaseous mixture including phosphine. A sensor (74a-c) senses the concentration of phosphine for atmosphere of the region (44a-c) and a flow controller (38) controls flow to the region (44a-c) in response to the sensed concentration. A recycling passage (42) removes a portion of the atmosphere from the region and returns the atmosphere to create a recycle flow through the region. In addition, a gas mixing system (20) is provided to supply the non flammable mixture by mixing phosphine from a phosphine source (24) and an inert substance from an inert substance source (22).

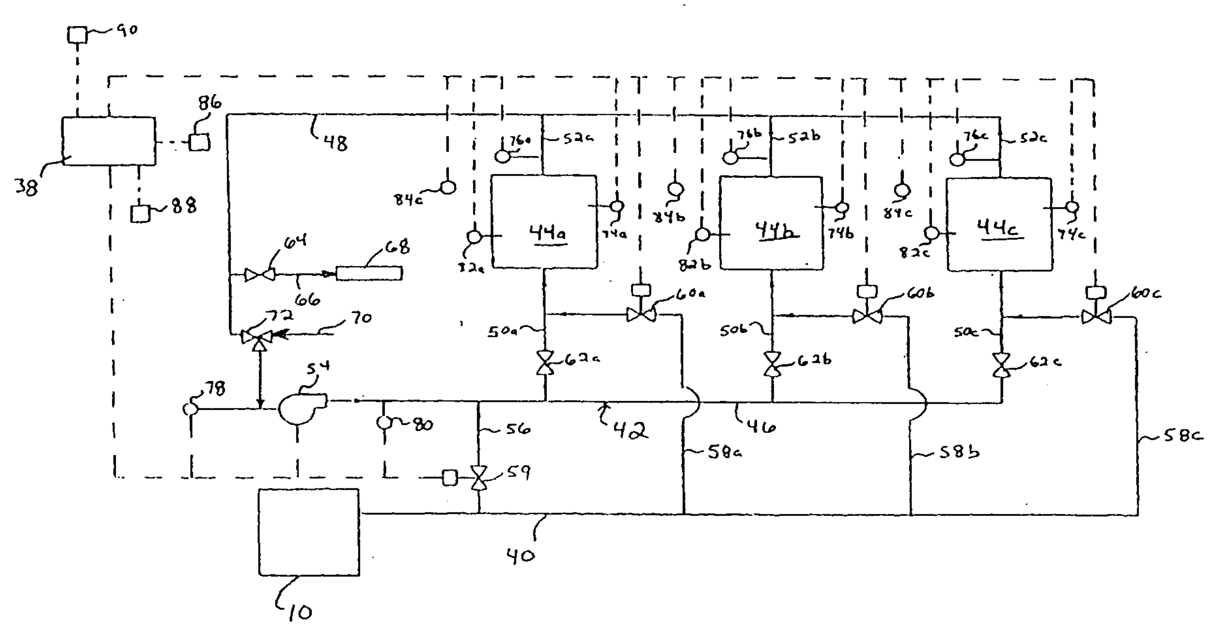

Fig. 1

EP 0 865 731 A1

Description

The present invention relates to a gas fumigation method and system, more particularly to a method and system for fumigating a region with a non-flammable gaseous mixture containing phosphine.

Pests are a nuisance to many different types of businesses. In agricultural and food production related industries, infestations of pests, such as rodents or insects, cause significant problems. Pests often contaminate crops or food products stored in silos and render them unfit or unappealing for use as foods or food ingredients. In addition, the pests feed on stored crops and food products causing a significant losses.

Although there are many different ways of controlling pests, most current pest control processes rely on the use of chemicals. Pest control methods using chemicals can be effective at destroying or limiting pest infestations, but they often have significant drawbacks. Most pesticidal chemicals in use today are toxic to humans. Therefore, workers must be isolated from areas in which the chemicals are being applied. In addition, crops or food products exposed to pesticidal chemicals may contain potentially dangerous chemical residues, requiring further processing to remove the residues.

One type of pesticidal chemical is phosphine (PH_3). Phosphine is a gas capable of being used as a pesticidal fumigant to eliminate pests and to reduce pest infestations. This gas is advantageous because it does not leave a residue after being used as a fumigant. However, phosphine gas is extremely flammable in air unless it is mixed with other gases and diluted sufficiently. Because of this flammability risk, pest control processes using relatively pure phosphine can be very dangerous.

One type of phosphine gas fumigation process uses phosphine gas generated from metal phosphide, such as aluminium phosphide or magnesium phosphide, shaped into tablets or pellets, and optionally placed into separate packets. When the metal phosphide is exposed to water, such as moisture in atmosphere, it reacts with the water to generate phosphine gas.

Pest fumigation relying on the generation of phosphine from metal phosphides have a number of disadvantages. Flammable concentrations of phosphine can accumulate and thereby create a significant risk of fire or explosion. Generation of phosphine from metal phosphides often depends on climatic conditions, such as humidity and temperature. Workers can become exposed to toxic and potentially dangerous levels of phosphine because they must enter confined areas to deploy or retrieve unreacted metal phosphides and its packaging material. Because of this risk, a significant number of workers must have personal protective equipment, rescue gear, and ongoing training. In addition, the residual material of the metal phosphide reaction must be properly handled, packaged, transported, treated, and disposed.

The reaction of metal phosphides and water is difficult to control and frequently requires a significant amount of time to be terminated. The use of excess amounts of metal phosphide to account for potential reaction inefficiencies sometimes generates excessive amounts of phosphine. Continued generation of phosphine is difficult to terminate without exposing workers to toxic and potentially flammable amounts of phosphine. The difficulty in controlling the generation of phosphine often establishes a wide range of different phosphine concentrations.

Although large amounts of metal phosphides could achieve a pesticidal atmosphere in a short amount of time, the use of excessive amounts of raw material and disposal cost limit such approaches. Typically, the reaction time of the metal phosphides and the means by which phosphine gas is distributed prevent rapid establishment of a pesticidal atmosphere.

When phosphine is mixed with other gases, the resulting gaseous mixture can be effective at fumigating pests. For example, US Patent No. 4,889,708 discloses a pressurised mixture of a diluent gas and phosphine gas in a container adapted to release the mixture of gases during fumigation. However, there is a need for systems capable of managing the flow of such gaseous mixtures during fumigation of particular areas. In addition, there is a need for systems capable of mixing gases on site during fumigation to allow for separate supply of components of the mixtures.

After an area is fumigated to destroy pests, certain measures must often be taken to prevent pests from reinfesting the area. The current means for protecting products from reinfestation involve spraying liquid chemicals directly onto the products. However, the use of such chemicals requires a quarantine period while the chemicals degrade to low concentrations. During this quarantine period, which sometimes lasts for a number of days, the product cannot be used.

In light of the foregoing, there is a need in the art for improving phosphine gas fumigation.

Accordingly, the present invention is directed to a gas fumigation method and system that substantially obviates one or more of the limitations of the related art. In particular, the present invention is directed to gas fumigation with non-flammable gaseous mixtures containing phosphine and at least one inert gas.

In its broadest aspect therefore, the invention includes a gas fumigation method comprising the steps of flowing phosphine from a phosphine source, flowing an inert substance from an inert substance source, mixing the phosphine and the inert substance to form a gaseous mixture, controlling at least one of flow of the phosphine from the phosphine source and flow of the inert substance from the inert substance source so that the gaseous mixture is non-flammable in air, and passing the gaseous mixture into a region to fumigate the region.

More particularly, the invention provides a method of fumigation comprising mixing phosphine and an inert substance to form a gaseous mixture, controlling the

flow of at least one of the phosphine and the inert substance so that the gaseous mixture is non-flammable in air and passing the flow of gaseous mixture into a region to fumigate the region, characterised by sensing the concentration of phosphine in the gaseous mixture and/or in the atmosphere of the region, and/or sensing the temperature in the region, and regulating the flow of at least one of the gaseous mixture, the phosphine and the inert gas based on the sensed phosphine concentration/temperature.

In another aspect, a system for gas fumigating a region is provided. The system includes a phosphine source, an inert substance source, a mixer fluidly coupled to the phosphine source and the inert substance source to form a gaseous mixture including phosphine flowing from the phosphine source and inert substance flowing from the inert substance source, the gaseous mixture passing from the mixer to the region during gas fumigation, and a flow controller controlling at least one of flow of the phosphine from the phosphine source to the mixer and flow of the inert substance from the inert substance source to the mixer so that the gaseous mixture is non-flammable in air.

In a further aspect, a method of fumigating a product storage region is provided. The method includes the steps of removing a portion of atmosphere from the region and returning the portion back to the region so as to create recycle flow of the atmosphere through the region, flowing a gaseous mixture from a source of the gaseous mixture to the region, the gaseous mixture including phosphine and being non-flammable in air, sensing concentration of phosphine for the atmosphere of the region, and controlling flow of the gaseous mixture to the region based on the sensed concentration of phosphine to form a pesticidal concentration of phosphine in the region.

In an additional aspect, a system for fumigating a product storage region is provided. The system includes a source of a gaseous mixture capable of fumigating pests, the gaseous mixture including phosphine and being non-flammable in air, a sensor for sensing concentration of phosphine for atmosphere of the region, a flow controller for controlling flow of the gaseous mixture from the source to the region based on the sensed concentration of phosphine to form a pesticidal concentration of phosphine in the region, and a recycling passage for removing a portion of the atmosphere from the region and returning the portion back to the region so as to create recycle flow of the atmosphere through the region.

The invention will now be described by way of example and with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a gas fumigation system in accordance with an embodiment of the invention wherein broken lines represent electrical interconnections and unbroken lines represent fluid couplings; and

Figure 2 is a schematic view gas mixing system for use with the gas fumigation system of Figure 1.

In the accompanying drawings the same reference numbers are, wherever possible, used in the drawings and the description to refer to the same or like parts.

In accordance with the invention, there is provided a gas fumigation system. As shown in Figure 1, the fumigation system includes a source 10 of a fumigant gas mixture, a plurality of regions 44a, 44b, and 44c, a recycling passage 42 for recycling atmosphere through the regions 44a-44c, and a supply line 40 for supplying the gaseous mixture to the recycling passage 42 and the regions 44a-44c to fumigate the regions 44a-44c.

The regions 44a-44c are any type of partially enclosed or enclosed areas in which gas fumigation is desired. Normally, the walls of the regions 44a-44c allow for some leakage of gas from the regions 44a-44c, however the invention may also be used for gas tight enclosures. In one embodiment of the invention, the regions 44a-44c are storage areas, such as silos, for food products or agricultural crops, such as grain. In another embodiment of the invention, the regions 44a-44c are areas on a vehicle, such as a compartment on a truck or a railroad car. The present invention can be practised to fumigate a number of different types of regions 44a-44c and any number of different types of products stored in each of the regions 44a-44c.

In a preferred embodiment of the invention, the gaseous mixture provided the source 10 includes phosphine mixed with one or more inert gases, such as carbon dioxide and/or nitrogen, which are non-flammable in air. Preferably, the gaseous mixture provided by the source 10 includes a sufficient amount of the inert gas to dilute the phosphine sufficiently enough to render the mixture itself non-flammable in air. The use of a non-flammable gaseous mixture is significantly safer than gas fumigation processes in which high concentrations of flammable phosphine are used. In addition, when carbon dioxide is one of the inert gases blended in the mixture, the carbon dioxide acts synergistically with the phosphine in the mixture to enhance pest fumigation and limits the amount of phosphine required.

One suitable mixture provided by the source 10 includes phosphine in an amount of less than about 3.1% by volume with the remainder of the mixture being inert gas, such as carbon dioxide and/or nitrogen. Another suitable mixture includes phosphine in an amount of less than about 5% by volume with an inert gas remainder. In addition, the non-flammable gaseous mixture in the source 10 may be any of the gaseous mixtures disclosed in the above-mentioned US Patent No. 4,889,708.

In one embodiment of the invention, the source 10 is a pressure vessel containing the non-flammable gaseous mixture. Such a source is advantageous when the gaseous mixture is blended at an off-site location and transported to where fumigation is to take place. With

this arrangement, the potentially dangerous generation of phosphine is confined to a facility having sufficient safety measures for handling flammable concentrations of phosphine. Use of a pressure vessel containing the gaseous mixture also does not require transportation of flammable concentrations of phosphine.

In another embodiment, the gaseous mixture source 10 includes a gas mixing system 20 shown in Figure 2. The gas mixing system 20 includes a source 22 of the inert substance, a source 24 of phosphine, and a gas mixer 26 fluidly coupled to the sources 22 and 24 to blend inert substance flowing from the inert substance source 22 with phosphine flowing from the phosphine source 24.

The inert substance source 22 is preferably a pressure vessel containing an inert substance such as carbon dioxide, nitrogen, or a mixture of carbon dioxide and nitrogen. Alternatively, the inert substance source 22 is an inert substance generator capable of generating carbon dioxide or nitrogen in a chemical reaction. When the inert substance in the inert substance source 22 is initially in liquid form, such as when the inert substance is pressurised in a pressure vessel, a vaporiser (not shown) is preferably located between the inert substance source 22 and the mixer 26 to heat the inert substance and thereby change its phase from a liquid to a gas.

The phosphine source 24 is preferably a pressure vessel containing substantially pure phosphine. Alternatively, the phosphine source 24 is a phosphine generator capable of generating phosphine, for example, from the reaction of metal phosphide and water. When the phosphine source 24 is a phosphine generator, an unfilled pressure vessel (not shown) is also preferably in selective fluid communication with the source 24 to store excess phosphine produced in the generator.

The gas mixer 26 is a static or dynamic gaseous mixer capable of inducing turbulent flow for mixing. For example, the gas mixer 26 may be a "T" shaped connector, a length of tubing having internal baffles, or a length of tubing having a segment of chain in its flow path to cause blending of the inert substance flowing from the inert substance source 22 and the phosphine flowing from the phosphine source 24. As shown in Figure 2, an inert substance flow meter 28 and an inert substance flow valve 30 are positioned between the inert substance source 22 and the gas mixer 26 to measure the flow rate of inert substance flowing from the source 22 and to vary the rate of flow, respectively. Similarly, a phosphine flow meter 32 and phosphine flow valve 34 are positioned between the phosphine source 24 and the gas mixer 26 to measure the flow rate of inert substance flowing from the source 24 and to vary the rate of flow, respectively. In addition, a gas sensor 36 is provided to sense concentration of phosphine and/or concentration of inert substance in the gaseous mixture flowing from the gas mixer 26. The gas sensor 36 may also measures the flow rate of the gaseous mixture produced in the gas mixing system 20.

A controller 38, which includes one or more microprocessors, preferably controls operation of both the overall gas fumigation system shown in Figure 1 and the gas mixing system 20 shown in Figure 2. During control of the gas mixing system 20, the controller 38 receives signals from the inert substance flow meter 28, the inert substance flow valve 30, the phosphine flow meter 32, the phosphine flow valve 34 and the gas sensor 36, and sends controlling signals to the inert substance flow valve 30 and the phosphine flow valve 34 to control flow of the inert substance and/or the phosphine flowing to the gas mixer 26.

Preferably, the controller 38 controls the flow of the phosphine and the flow of the inert substance prior to mixing in the gas mixer 26 to ensure that the phosphine is sufficiently diluted with the inert substance to create a non-flammable mixture. In addition, the controller 38 optionally controls the mixing of the inert substance and the phosphine based on sensed conditions of the gas fumigation system, such as concentrations of phosphine for atmosphere in the regions 44a-44c and temperatures in the regions 44a-44c, as explained below.

In an embodiment of the invention, the gas mixing system 20 shown in Figure 2 is mounted on a wheeled chassis, such as a trailer, or on a vehicle, such as an automobile, a boat, or a railroad car, so that the gas mixing system 20 may be transported to different locations and connected to regions requiring fumigation. Alternatively, the gas mixing system 20 may be mounted on a vehicle and supplies gaseous mixture to a region located on the vehicle itself.

Referring back to Figure 1, the recycling passage 42 includes a common feed passage 46, a common exhaust passage 48, branch inlet passages 50a, 50b, and 50c in direct fluid communication with respective regions 44a-44c, and branch outlet passages 52a, 52b, and 52c also in direct fluid communication with respective regions 44a-44c. A blower 54 is positioned in the recycling passage 42 between the common exhaust passage 48 and the common feed passage 46. The controller 38 regulates the speed of the blower 54 to control flow through the recycling passage 42 and the regions 44a-44c. Preferably, the controller 38 operates the blower continuously during fumigation to ensure adequate distribution of gaseous mixture through the regions 44a-44c.

During operation of the blower 54, the branch outlet passages 52a-52c remove a portion of the atmosphere in respective regions 44a-44c and feed this atmosphere into the common exhaust passage 48. After passing through the common exhaust passage 48, the common feed passage 46 distributes the atmosphere to each of the branch inlet passages 50a-50c, which then feed the atmosphere to the respective regions 44a-44c. The flow in the recycling passage 42 causes flow through the regions 44a-44c and mixing of atmosphere from each of the regions 44a-44c. This provides fumigation of essen-

tially all of the space in the regions 44a-44c and conserves the amount of gaseous mixture used during fumigation. Conservation of the gaseous mixture is beneficial because it reduces the amount of phosphine released into the environment.

Valves 62a, 62b, and 62c are provided in respective branch inlet passages 50a-50c to control flow of the atmosphere to each of the individual regions 44a-44c. The valves 62a-62c are either manual flow control valves or automatic valves controlled by the controller 38. When one or more of the regions 44a-44c is empty and does not require fumigation, the corresponding valves 62a-62c are closed to prevent flow to these regions and conserve the gaseous mixture.

As shown in Figure 1, a recycle flow feed line 56 is coupled between the supply line 40 and the common feed passage 46, and region feed lines 58a, 58b, and 58c are coupled between the supply line 40 and respective branch inlet passages 50a-50c. The recycle flow feed line 56 passes the gaseous mixture from the supply line 40 to the common feed passage 46, and the region feed lines 58a-58c pass the gaseous mixture from the supply line 40 to the respective branch inlet passages 50a-50c. This configuration allows for introduction of the gaseous mixture into the recycling passage and into each the regions 44a-44c during fumigation of each of the regions 44a-44c.

A valve 59 is positioned in the recycle flow feed line 56 to regulate flow of the gaseous mixture through the recycle flow feed line 56. Similarly, valves 60a, 60b, and 60c are positioned in respective region feed lines 58a-58c to regulate flow of the gaseous mixture through each of the region feed lines 58a-58c. As shown, the valves 58 and 60a-60c are preferably automatic flow control valves controlled by the controller 38 in response to various sensed conditions of the system, as explained below.

Preferably, structure is provided to vent atmosphere from the regions 44a-44c to ambient air. As shown in Figure 1, a valve 64, optionally controlled by the controller 38, selectively places the common exhaust passage 48 in flow communication with a vent 66. The vent 66 is in flow communication with ambient air outside of the system and preferably includes a scrubber or filter 68 for removing potentially dangerous gases, such as phosphine.

An ambient air intake 70 is also provided to introduce ambient air into the recycling passage 42 and the regions 44a-44c. A valve 72 positioned in the common exhaust passage 48 is movable between a first position, in which the valve 72 allows recycle flow of atmosphere through the common exhaust passage 48 and blocks flow through the intake 70, and a second position, in which the valve 72 blocks recycle flow through the common exhaust passage 48 and allows flow of ambient air from the air intake 70 into a portion of the common exhaust passage 48 between the valve 72 and the blower 54.

Preferably, the controller 38 controls movement of the valve 72 between the first and second positions to selectively introduce ambient air into the regions 44a-44c. To dilute potentially harmful gases in the regions 44a-44c rapidly, for example, when workers are to enter the regions 44a-44c, the controller 38 places both the air intake 70 and vent 66 in flow communication with the common exhaust passage 48.

Various sensors are provided to sense conditions of the system during a fumigation procedure and to provide feedback signals to the controller 38 based on the sensed conditions. As shown in Figure 1, phosphine sensors 74a, 74b, and 74c are provided to sense concentrations of phosphine in the respective regions 44a-44c and to send corresponding signals to the controller 38. Phosphine sensors 76a, 76b, and 76c are also provided to sense concentrations of phosphine for atmosphere flowing in respective branch outlet passages 52a-52c and to send corresponding signals to the controller 38. In addition, phosphine sensors 78 and 80 are provided to sense phosphine concentrations in the recycling passage 42 at the inlet and outlet ends of the blower 54 and to send corresponding signals to the controller 38.

The controller 38 controls the valves 30, 34, 58, 60a-60c, and 62a-62c and the blower 54 in response to the phosphine concentrations sensed by the phosphine sensors 74a-74c, 76a-76c, 78, and 80. This enables the controller 38 to regulate the phosphine concentration for each of the regions 44a-44c during a fumigation procedure. Preferably, the controller 38 manages the phosphine concentration in the regions 44a-44c to conserve the gaseous mixture while effectively fumigating pests in the regions 44a-44c.

For example, the controller 38 may maintain a phosphine concentration in the regions 44a-44c of from about 10 ppm to about 700 ppm, or from about 20 ppm to about 250 ppm. During pest fumigation, the controller 38 establishes and maintains a predetermined phosphine concentration in the regions 44a-44c for a period of time sufficient to eliminate any pests, and then the controller 38 maintains the phosphine concentration at a level below the predetermined level to reduce the likelihood of pest entry into the regions. In addition, the controller 38 can increase phosphine concentrations when pests may have entered the regions 44a-44c or become more active in the regions 44a-44c, such as when food products or crops are placed in the regions 44a-44c.

Preferably, the controller 38 adjusts the concentration of phosphine in each of the regions 44a-44c based on conditions related to the likelihood of pest activity in the regions 44a-44c. The controller 38 preferably conserves the amount of gaseous mixture used in the regions 44a-44c to provide optimal pest control at a minimal cost and with a reduced risk of releasing potentially toxic levels of gases into the environment.

As shown in Figure 1, temperature sensors 82a, 82b, and 82c are provided in respective regions 44a-

44c. The temperature sensors 82a-82c sense temperature in the regions 44a-44c and provide corresponding signals to the controller 38 to allow for control of the phosphine concentrations in the regions 44a-44c based on this sensed temperature. At cooler temperatures, certain pests become dormant or inactive, and at relatively higher temperatures some regions to be fumigated experience a chimney effect in which extreme temperature gradients heat gases and force them rapidly upwards. In addition, phosphine pest fumigation is more effective at higher temperatures. The controller 38 preferably adjusts the concentrations of phosphine in the regions 44a-44c to compensate for the effects of temperature fluctuations.

The gas fumigation system also preferably includes phosphine sensors 84a, 84b, and 84c, an electronic data recorder 86, and an audible and visual warning alarm 88. The phosphine sensors 84a-84c are situated outside of the regions 44a-44c and recycle passage 42 to detect any leakage of phosphine from the system into the ambient air surrounding the system. The phosphine sensors 84a-84c provide a "fence line" monitoring of the area surrounding the system and could be any type of gas sensor, such as a laser beam sensor or point sensor.

The controller 38 receives signals from the phosphine sensors 84a-84c and stores data regarding the sensed phosphine concentrations in the data recorder 90. If the concentration of phosphine sensed by the sensors 84a-84c reaches an unsafe level, the controller 38 preferably activates an alarm 88 to warn individuals in the area about the increased levels of phosphine. In addition, the controller 38 may also close the valves 30, 34, 58, 60a-60c, and 62a-62c, and deactivate the blower 52, to prevent additional leakage of phosphine from the system.

Preferably, a communication device 90 is connected to the controller 38 to allow for remote monitoring and control of the gas fumigation system via another corresponding communication device (not shown). The communication device 90 is any type of device capable of sending and receiving data so that the controller 38 can be monitored and adjusted. For example, the communication device 90 may be a conventional telephone modem, a wireless telephone modem, a radio, or any other type of communication device allowing two way exchange of information.

Methods of fumigating pests with the structure shown in Figures 1 and 2 are discussed below. Although the invention is described in association with this structure, the method of the invention in its broadest sense could be practised with other structure.

During a pest fumigation procedure, the controller 38 initiates operation of the blower 54 to establish flow in the recycling passage 42. The flow in the recycling passage 42 draws atmosphere from the regions 44a-44c via the branch outlet passages 52a-52c and returns atmosphere to the regions 44a-44c via the branch inlet passages 50a-50c.

When the gaseous mixture source 10 is a pressure vessel containing the gaseous mixture, a valve on the vessel is opened to allow flow of the gaseous mixture from the source 10. When the gaseous mixture source 10 includes the gas mixing system 20 shown in Figure 2, flow of the inert substance, such as carbon dioxide and/or nitrogen, and flow of phosphine is initiated from the respective sources 22 and 24. If the inert substance source 22 is an inert substance generator, the inert substance generator generates the inert substance preferably throughout a fumigation process. Similarly, if the phosphine source 24 is a phosphine generator, the phosphine generator generates the phosphine throughout fumigation. Optionally, the inert substance source 22 includes a pressure vessel containing the inert substance, and/or the phosphine source 24 includes a pressure vessel containing the phosphine.

The controller 38 controls the inert substance flow valve 30 and phosphine flow valve 34 to mix the non-flammable mixture of the phosphine and inert substance in the mixer 26. The controller 38 receives signals from the inert substance flow meter 28, the phosphine flow meter 32, and the gas sensor 36 to adjust flow through the valves 30 and 34 based on flow rate of the inert substance, flow rate of the phosphine, concentration of the phosphine and/or inert substance in the mixture, and optionally the flow rate of the mixture. The information provided by the flow meters 28 and 32 and the gas sensor 36 allows the controller 38 to constantly monitor and manage the relative concentrations of inert substance and phosphine in the gaseous mixture to ensure that the mixture is non-flammable. In addition, the gas mixing system 20 is capable of adjusting the relative proportions of the phosphine and the inert substance during fumigation.

Although the gas mixing system 20 preferably mixes the phosphine and inert substance throughout the fumigation process, the controller 38 optionally also controls the valves 30 and 34 to allow for flow of the inert substance alone rather than the gaseous mixture. This type of control is sometimes preferable at the beginning of a pest fumigation procedure to purge atmosphere from the regions 44a-44c with the inert substance before flowing the gaseous mixture into the regions 44a-44c.

When the gaseous mixture flows through the supply line 40 from the source 10, the controller 38 controls the valves 58 and 60a-60c to allow for flow of the gaseous mixture into the recycling passage 42 and the regions 44a-44c. Initially the gaseous mixture is diluted when it combines with the atmosphere present in the regions 44a-44c and the recycling passage 42 before initiation of gas fumigation. Over time, more gaseous mixture flows into the recycling passage 42 and the regions 44a-44c, and eventually the concentration of phosphine in the regions 44a-44c increases to a pesticidal level.

The flow in the recycling passage 42 provides mixing of the atmospheres of each of the regions 44a-44c.

This recycle flow maintains relatively uniform concentration of phosphine throughout each of the regions 44a-44c during fumigation. In addition, the recycle flow reduces the amount of gaseous mixture required during fumigation because the gaseous mixture initially introduced into the recycling passage 42 and the regions 44a-44c continuously passes through the regions 44a-44c.

As gas flows from the gas supply 10, the controller 38 receives input from the phosphine sensors 74a-74b and 76a-76c to determine the phosphine concentration in the atmosphere of the regions 44a-44c. The controller 38 also receives input from the phosphine sensors 78 and 80 and the temperature sensors 82a-82c to determine the concentration of phosphine in the recycle flow and the temperature in the regions 44a-44c.

Based on the sensed phosphine concentrations and temperatures, the controller 38 controls the valves 30, 34, 58, 60a-60c, and 62a-62c and the blower 54 to regulate the phosphine concentration in each of the regions 44a-44c. The controller 38 optionally controls the valves 30, 34, 58, 60a-60c, and 62a-62 in a number of different ways to modify flow. For example, the controller 38 may control the valves 30, 34, 58, 60a-60c, and 62a-62 to provide for continuous, continuous and variable, or pulsing flow of the gaseous mixture to each of the regions 44a-44c independently.

In the embodiment shown in Figure 1, the controller 38 varies the rate of a continuously operating blower 54 to modify flow through the recycling passage 42. However, the flow through the recycling passage 42 can be varied in other ways and by other means. For example, the flow in the recycling passage 42 could be pulsed by operating the blower 54 intermittently. In addition, the blower 54 could have a bypass selectively placing the inlet of the blower 54 in flow communication with the outlet of the blower 54, a throttle opening could be provided in the recycling passage 42, or multiple blowers could be provided. Optionally, the controller 38 monitors operation of the blower 54 and ceases flow of the gaseous mixture in the event of failure of the blower 54.

When phosphine is depleted from the system, for example, due to leakage from walls of the regions 44a-44c, the controller 38 continues the supply of the gaseous mixture and adjusts flow of the gaseous mixture to make up for the loss. Preferably, the controller 38 maintains a predetermined concentration of phosphine in the regions 44a-44c for a sufficient amount of time to exterminate any pests in the regions 44a-44c. Thereafter, the controller 38 maintains a lower concentration of phosphine in the regions 44a-44c to ensure that pests will not attempt to reinfest the regions 44a-44c.

The controller 38 preferably increases the concentration of phosphine in the regions 44a-44c when pest infestations are more likely. For example, the controller 38 increases the concentration of phosphine in the regions 44a-44c after a product, such as grain, is added to the region. This increase of phosphine concentration fumigates any pests in the added product.

During fumigation, the controller 38 preferably monitors the phosphine concentration sensors 84a-84c to detect increased concentrations of phosphine leaking from the regions 44a-44c or other areas of the gas fumigation system. The recorder 86 maintains a record of the concentrations sensed by the sensors 84a-84c to allow for monitoring of the system. When the sensors 84a-84c sense potentially unsafe concentrations of phosphine, the controller 38 activates the alarm 88 to provide a warning to individuals in the area, and the controller 38 closes the valves 30, 34, 58, 60a-60c, and 62a-62c to prevent additional leakage from the system.

If desired, the fumigation process can be monitored from a remote location via the communication device 90. If adjustments to the fumigation process are desired, the communication device 90 allows for adjustment of the process from the remote location.

At the completion of the fumigation process, the controller 38 preferably adjusts the valve 64 and the valve 72 to vent atmosphere from the regions 44a-44c through the vent 66 and to introduce fresh ambient air through the air intake 70. After a sufficient amount of time, this diminishes the amount of gaseous mixture in the regions 44a-44c so that individuals may enter the regions 44a-44c.

Because the gas mixing system 20 and gas fumigation system regulate and control flows of gases, the present invention allows for controlled dosing of particular amounts of phosphine in each the regions 44a-44c and for relatively instantaneous start up and shut down of gas flows. Controlling flow of the gaseous mixture to the regions 44a-44c, rather than generation of phosphine in the regions, reduces the likelihood of residue being left in the regions 44a-44c and eliminates the need for high humidity or external water supply to the regions 44a-44c.

The present invention flows non-flammable gaseous mixtures into the regions 44a-44c, rather than allowing flammable concentrations of phosphine to be introduced or build up in the regions 44a-44c. Therefore, the present invention is safer than other phosphine fumigation methods and systems.

In particular, the present invention has a significant number of advantages as compared to pest fumigation approaches in which phosphine is generated from metal phosphides without providing for control of gas flow or control of gas mixing. Risk of fire is extremely low because the gaseous mixture is non-flammable and diluted initially when the mixture combines with atmosphere in the regions 44a-44c. The release and control of the gaseous mixture is relatively independent of climatic conditions.

Potential worker exposure to high concentrations of phosphine is minimised because the non-flammable gaseous mixture is contained in fluid handling equipment. In addition, workers do not have to enter the regions 44a-44c and perform tasks such as removal and

disposal of residual mater. This reduces the number of workers required to perform fumigation.

The present invention enables control and direct measurement of phosphine release and termination of the release on demand. Control of flow in the recycling passage 42 can be used to provide a desired concentration of phosphine in the regions 44a-44c. The method and system of the present invention can establish a uniform pesticidal atmosphere at a rate dependent upon the geometry of the regions 44a-44c and the rate of recycle flow.

The method and system of the present invention can, rather than relying on liquid chemicals, maintain a relatively low concentration of phosphine in the regions 44a-44c over a period of time to reduce infestations by mobile pests. Products in the regions 44a-44c are available for use as soon as the phosphine is ventilated from the regions 44a-44c without requiring a significant quarantine period.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope of the invention. For example, the present invention could be used to manage flow of flammable gases other than phosphine, to provide for fumigation of any numbers of regions, or to provide for fumigation of a single region, rather than a plurality of regions. In addition, the gas mixing system of Figure 2 could be used in combination with a gas fumigation system different from that shown in Figure 1.

Claims

1. A method of fumigation comprising mixing phosphine and an inert substance to form a gaseous mixture, controlling the flow of at least one of the phosphine and the inert substance so that the gaseous mixture is non-flammable in air and passing the flow of gaseous mixture into a region to fumigate the region, characterised by sensing the concentration of phosphine in the gaseous mixture and/or in the atmosphere of the region, and/or sensing the temperature in the region, and regulating the flow of at least one of the gaseous mixture, the phosphine and the inert gas based on the sensed phosphine concentration/temperature.

2. A method according to Claim 1, comprising monitoring the temperature of product stored in the region and controlling the flow of the gaseous mixture based on the sensed temperature.

3. A method according to Claim 1 or Claim 2, comprising removing a portion of atmosphere from the region, returning the portion back to the region so as to create a recycle flow of the atmosphere, and combining the gaseous mixture with the recycle flow.

4. A method according to Claim 3, wherein the step of passing the flow into the region comprises controlling at least one of the combined flow of the gaseous mixture and the recycle flow, the method comprising controlling the flow of the gaseous mixture prior to combining the gaseous mixture with the recycle flow.

5. A method according to Claim 3 or Claim 4, wherein the recycle flow is continuous and wherein the method includes the step of varying the recycle flow.

6. A method according to any preceding Claim, comprising maintaining a predetermined phosphine concentration in the region for a period of time sufficient to eliminate pests in the region, and then maintaining the concentration of phosphine at a level below the predetermined level so as to reduce the likelihood of pest entry into the region.

7. A method according to any preceding Claim, comprising adding product to the region and increasing the concentration of phosphine in the region to fumigate pests in the added product.

8. A method according to any preceding Claim, wherein the step of passing the flow into the region comprises controlling the flow of the gaseous mixture to provide a plurality of separate flows of the gaseous mixture to a plurality of separate regions.

9. A method according to Claim 3, or to any of Claims 4 to 8 when dependent on Claim 3, wherein the step of sensing phosphine concentration comprises sensing the phosphine concentration in at least one of the region itself and the recycle flow.

10. A method according to any preceding Claim, comprising sensing phosphine concentration in an area outside of the region and interrupting flow of the gaseous mixture to the region and/or activating an alarm when the sensed phosphine concentration in the area is above a predetermined concentration and/or recording the sensed phosphine concentration in the area.

11. A method according to any preceding Claim, comprising monitoring and adjusting the controlling step via a communication device located away from the region.

12. A method according to any preceding Claim, wherein the inert substance is selected from the group consisting of carbon dioxide, nitrogen, and a mixture of carbon dioxide and nitrogen.

13. A method according to any preceding Claim, wherein the phosphine is drawn from a source comprising a pressure vessel containing phosphine gas.

14. A method according to any one of Claims 1 to 13, wherein the phosphine is drawn from a source comprising a phosphine gas generator, the method further including generating phosphine gas in the phosphine generator.

15. A method according to any preceding Claim, wherein the inert substance is drawn from a source comprising a pressure vessel containing the inert substance.

16. Apparatus for gas fumigating a region, comprising a mixer fluidly coupled to a phosphine source and to an inert substance source to form a gaseous mixture including phosphine and inert substance, a flow controller adapted for controlling the flow of at least one of the phosphine and the inert substance to the mixer so that the gaseous mixture is non-flammable in air and means for passing the gaseous mixture to the region, characterised by sensor means for sensing at least one of: the concentration of phosphine and/or of inert substance in the gaseous mixture; concentration of phosphine in the atmosphere of the region; and temperature in the region, the flow controller being adapted to receive input from the sensor means and to regulate the flow of at least one of the gaseous mixture, the phosphine, and the inert substance based on the sensed concentration/ temperature.

17. Apparatus according to Claim 16, further comprising a recycling passage for removing a portion of atmosphere from the region and returning the portion back to the region so as to create a recycle flow, the recycling passage being in fluid communication with the mixer so that the gaseous mixture combines with the recycle flow.

18. Apparatus according to Claim 17, wherein the flow controller controls the flow of at least one of the combined flow of gaseous mixture and recycle flow, and the flow of the gaseous mixture prior to combining the gaseous mixture with the recycle flow.

19. Apparatus according to any one of Claims 16 to 18 comprising sensor means for monitoring temperature of product stored in the region, the flow controller being adapted to control the flow of gaseous mixture based on the sensed product temperature.

20. Apparatus according to any one of Claims 16 to 19 comprising sensor means for sensing phosphine concentration in an area outside of the region, the flow controller being adapted to interrupt flow of the gaseous mixture to the region when the sensed phosphine concentration in the area is above a predetermined concentration.

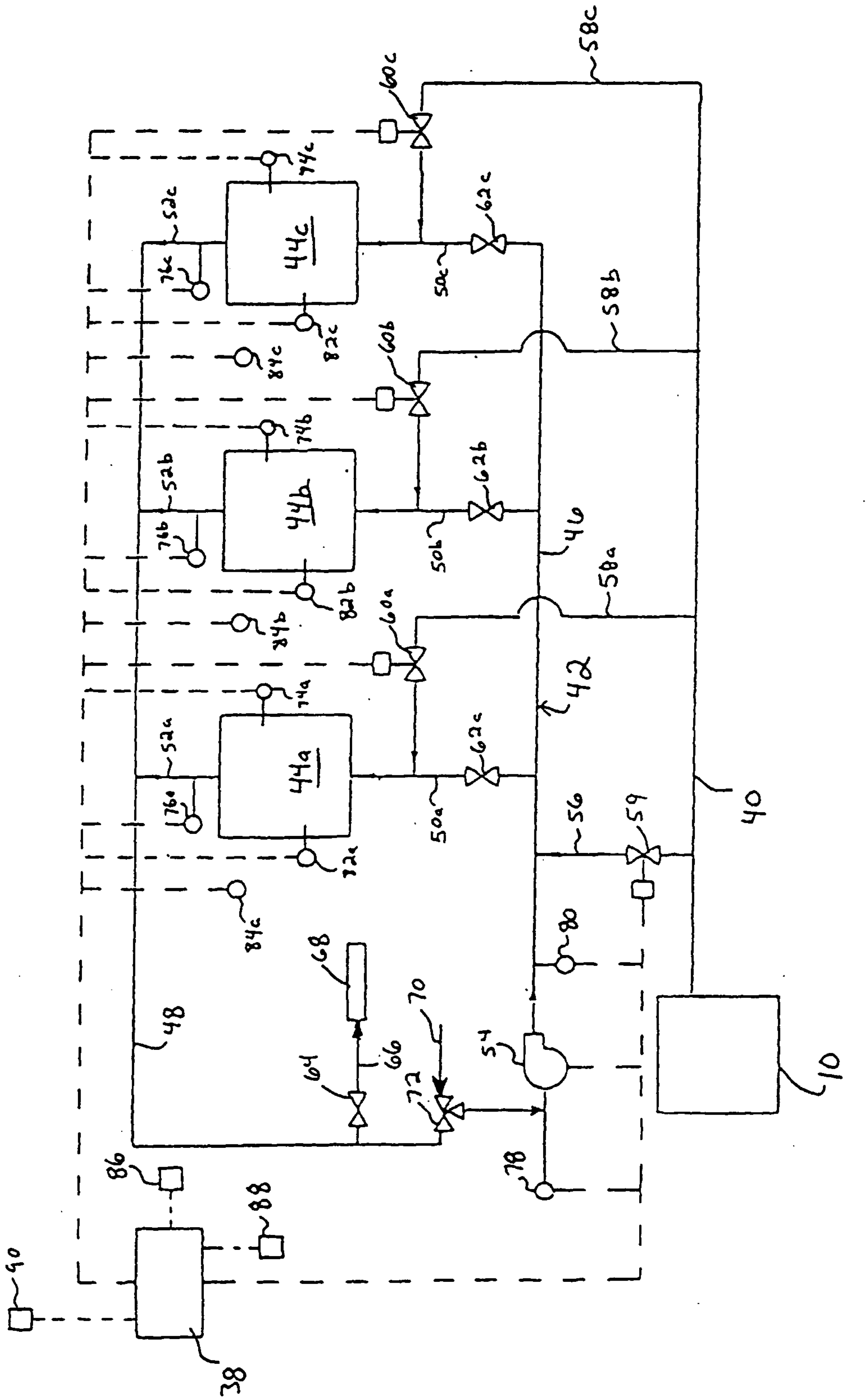
58c
60c
62c
44c
52c
74c
76c
50c
82c
84c
58b
60b
74b
52b
44b
62b
76b
50b
46
82b
84b
58a
60a
42
74a
52a
44a
62c
76a
50a
82a
56
59
40
84a
68
80
48
70
54
66
64
72
10
78
86
88
90
38

Fig. 1

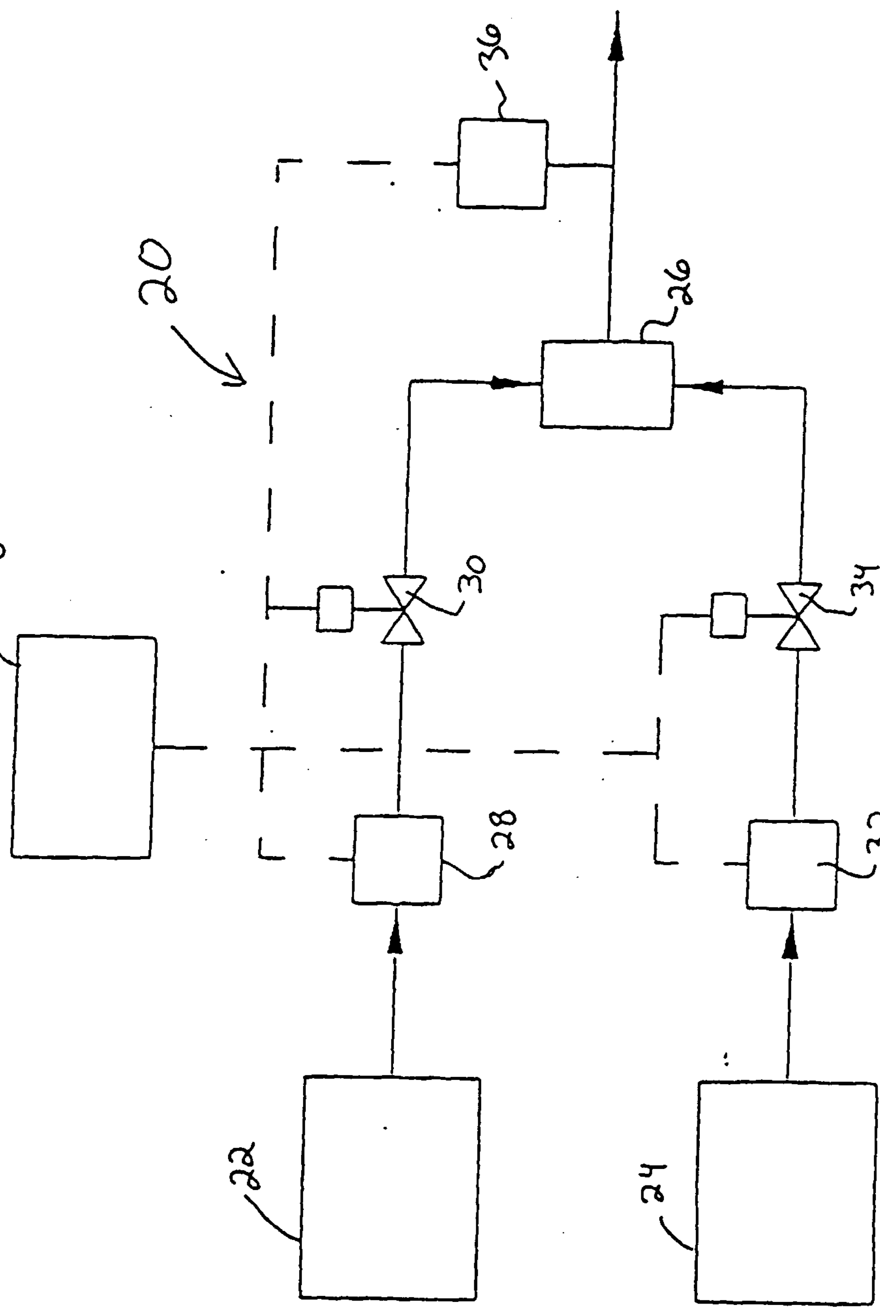

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 2028

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	FR 2 531 840 A (FREYBERG CHEM FAB WERNER) 24 February 1984 * page 12, line 1 - line 27 * * page 13, line 8 - page 15, line 10 * * claims; figures * ---	1-3,16, 17	A01M13/00 A23L3/3418 A01M17/00
X	FR 2 487 638 A (CABROL LUCIEN) 5 February 1982 * page 7, line 1 - page 8, line 20 * * claims; figures * ---	1-3,16, 17	
X A	EP 0 320 012 A (DEUTSCHE GES SCHAEDLINGSBEK) 14 June 1989 * column 3, line 1 - column 5, line 38 * * claims; figures * ---	1,16 2,3,17	
A	EP 0 318 040 A (DETIA FREYBERG GMBH) 31 May 1989 * page 3, line 30 - line 52 * * claims; figures * ---	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 5 163 361 A (FOX SETH F ET AL) 17 November 1992 * column 1, line 12 - line 26 * * claims; figures * ---	1,3,16, 17	A01M A23L A23B A01N
A	EP 0 702 895 A (DEUTSCHE GES SCHAEDLINGSBEK) 27 March 1996 * column 3, line 28 - line 38 * * column 12, line 37 - column 13, line 10 * * claim 20 * ---	1,16	
A	GB 2 250 200 A (IGROX CHEMICALS LIMITED) 3 June 1992 * claims; figures * --- -/--	1,3,16, 17	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 May 1998	Piriou, J-C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 2028

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	US 4 889 708 A (LATIF SHERIF ET AL) 26 December 1989 * claims * -----	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 May 1998	Piriou, J-C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document